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APPLICATION OF COMPUTER SIMULATION TECHNIQUES IN MILITARY EXERCISE CONTROL SYSTEM DEVELOPMENT

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Applied Psychological Services

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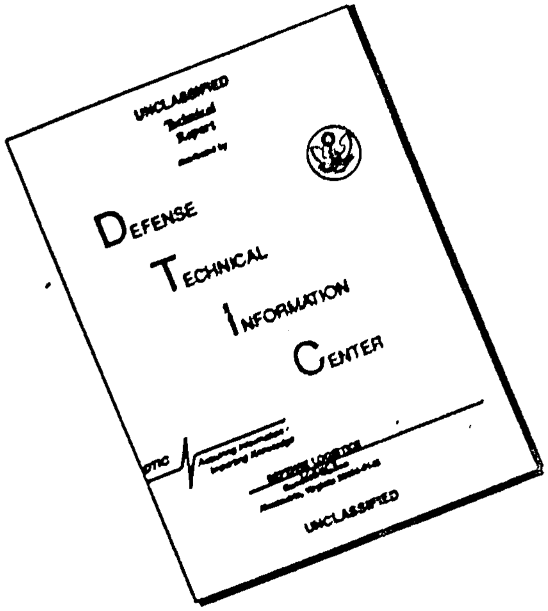

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A previously developed computer simulation model, NETMAN, was employed to evaluate a novel exercise monitoring and reporting system (EMARS). The application of the NETMAN model to EMARS possessed two purposes: (1) to investigate the flexibility of the NETMAN model by applying the model to a system which is in the conceptual stage of development, and (2) to provide a detailed evaluation of the EMARS concept.

The results supported contentions favoring the flexibility of the NETMAN model. The present results, when coupled with prior sensitivity and validation test results, serve to suggest that NETMAN possesses considerable utility.

The simulation results indicated that the EMARS concept possesses considerable advantage over one current exercise management system (TWSEAS), but some required EMARS modifications were indicated.

APPLICATION OF COMPUTER SIMULATION TECHNIQUES IN MILITARY EXERCISE CONTROL SYSTEM DEVELOPMENT

2. NETMAN Transportability and Application to an Exercise Control System

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EXECUTIVE SUMMARY

Background and Problem

Management and control of Army field exercises, as well as realistic methods for assessing unit proficiency through such exercises, represents a current concern to those responsible for establishing and maintaining combat readiness. Realistic and meaningful field exercise management, control, and assessment requires technologically advanced control and communication systems. The conceptual design for such an exercise monitoring and reporting system (EMARS) was previously developed but was not subjected to empirical evaluation.

A computer model, NETMAN, for evaluating such systems was also previously developed, tested for sensitivity, and validated. However, the adaptability/flexibility of NETMAN was never investigated. The present work allowed such a test by applying NETMAN to the conceptual EMARS' design and evaluating the results in terms of their practical implications for the design of the EMARS system.

Methods and Results

To simulate EMARS, several special NETMAN features were used and appropriate task analyses and network structures were developed.

The EMARS concept was evaluated by parametrically manipulating a number of NETMAN variables and assessing the impact on the system's performance and effectiveness. The variables investigated formed two groups: (1) physical, and (2) behavioral.

The effects of four physical variables on system performance were examined: (1) number of system entry messages (field situational reports), (2) number of messages generated per entry message (each report may generate more than one entry into the management, control, and assessment system), (3) length of the system entry message to the message to processing personnel, and (4) message length to staff personnel.

The effects on EMARS' performance of three system operator or behavioral variables were also assessed: (1) *proficiency*, (2) *precision*, and (3) aspiration.

Twenty-two computer runs were completed which allowed the effects of each NETMAN variable which was manipulated to be examined across three values and compared with a baseline. Whenever possible, the performance and effectiveness of the EMARS were also compared with the data from a prior NETMAN application (Siegel et al., 1979) which simulated a TWSEAS-type system communication net.

The findings generally suggested support for the EMARS concept. EMARS was found to be robust up to a message frequency of 10 per hour per operator--a rather high message frequency--and field message length of 100 characters per message. Within the parameters examined, staff message length had little effect on system performance. Also apparent was the rather consistent effect of operator proficiency, precision, and aspiration on EMARS' performance.

In comparison to the TWSEAS-type system, the EMARS' performance and effectiveness were observed to be rather consistently superior. This superiority was most marked when a large number of messages or lengthy messages are involved.

The NETMAN model was found to be fully adaptable for simulating the EMARS and, by implication, the utility and generality of NETMAN for such purposes seems supported.

Implications

The findings suggested advantages to the EMARS concept in terms of the simulated system's message processing time, throughput capacity, and a number of measures of "effectiveness." Accordingly, it seems that the EMARS concept is viable and should be pursued.

NETMAN'S ability to simulate the EMARS' concept tends to support claims favoring its adaptability. This contention is supported by the differential nature of the output data from the simulated EMARS and the TWSEAS-type system. The effectiveness differences between systems were orderly and could be meaningfully related to real differences in network structures.

Taken together with the sensitivity and validity testing (Siegel et al., 1979), the effectiveness and utility of NETMAN seems to have been reasonably demonstrated and NETMAN may be considered to represent a useful tool for evaluating message processing systems.

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CHAPTER I

INTRODUCTION AND BACKGROUND

Over the past several years, the Army Research Institute for the Behavioral and Social Sciences has supported efforts to develop: (1) a stochastic, behaviorally oriented computer simulation model (NETMAN) for simulating message throughput in Army tactical operations systems, and (2) a *conceptual design of an Exercise Monitoring* Assessment and Reporting System (EMARS).

Accordingly, the work described herein possessed two interrelated purposes: (1) to assess the merit of the EMARS concept as indicated through application of the NETMAN model, and (2) to evaluate the "effectiveness" or "utility" of the NETMAN model when the model is applied to a system which is in the conceptual phase of development.

Prior Developments

The basic concepts included in NETMAN are based on a prior operational computer model designed by Applied Psychological Services under the direction of the U.S. Army Research Institute for the Behavioral and Social Sciences. The earlier model, called MANMOD, simulates the U.S. Army's Tactical Operations System (TOS)--a battlefield information management and retrieval system. MANMOD (Siegel, Wolf, and Leahy, 1973) simulates the actions of up to six men functioning as action officers and of input-output device operators in a TOS.

NETMAN's predecessor, MANMOD, was written in FORTRAN for batch run processing on the CDC 3300 computer. Several unique aspects of the FORTRAN available on this system were used in the MANMOD. MANMOD was extensively tested (Siegel, Wolf, and Leahy, 1972).

Subsequently, MANMOD was expanded to operate in an interactive computer time sharing mode (Siegel, Wolf, Leahy, Bearde, and Baker, 1973). In this mode, the user can: (1) enter data via a terminal, (2) easily control changes in simulation parameters, and (3) assess their impact on output.

Later MANMOD was adapted for execution on the Univac 1108 computer. The system specific aspects of FORTRAN were removed from MANMOD and several simulation features were added to increase the overall realism of the simulation. The MANMOD was also modified

to allow the exchange of data with two independent computer models in such a way as to maximize the strong points of each computer model (Leahy, Siegel, and Wolf, 1975a, 1975b).

The simulation technique for task-by-task performance evaluation in MANMOD was adopted in the development of NETMAN (Siegel, Leahy, and Wolf, 1977).

Other features from MANMOD used in NETMAN include:

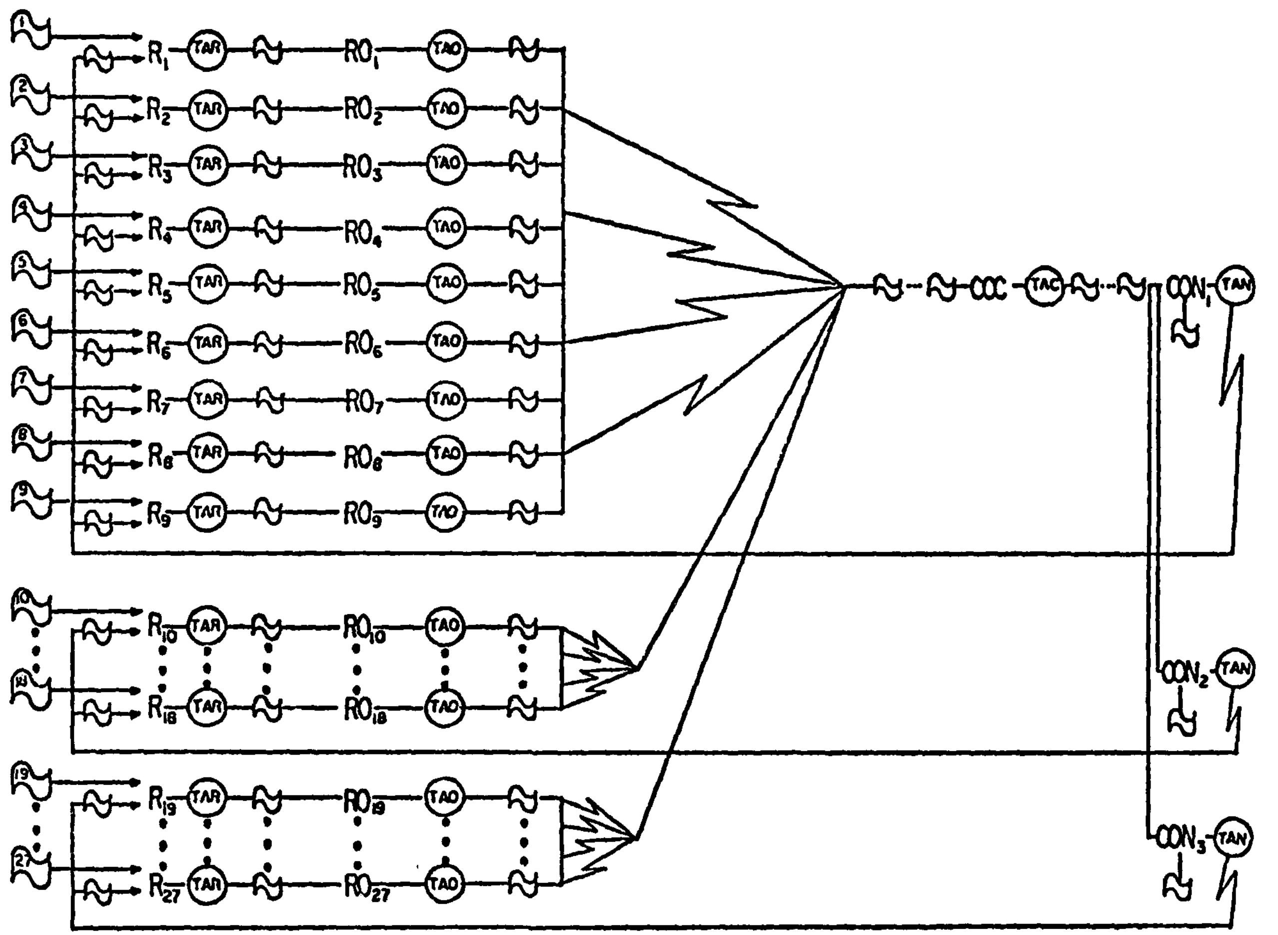
- Message queues are generated at the beginning of each simulation iteration
- Operator factors (such as speed, precision, level of aspiration, and stress threshold) influence performance
- Stochastic variation (i.e., random combinations of chance events) is used to increase the generalizability of the output
- Lists of inputs and run summaries are automatically provided with various additional outputs available as options.

Overview of the NETMAN Model

The NETMAN model simulates each person and each message involved in the data acquisition required for evaluating performance in field exercise control and monitoring systems. These personnel include up to 27 referees, 27 radio operators, and 3 controllers interacting in a fixed network of communication lines linked with a Central Computing Center (CCC).

The field exercise data acquisition situation which is being simulated may be viewed as a message processing network configured as shown in Figure 1. This exhibit symbolically displays 27 simulated referees (R_1 through R_{27}) receiving simulated input messages from independent sources as well as from one of three simulated controllers (CON 1, CON 2, or CON 3). Messages are indicated by the symbol .

Military field exercises of some form are observed by referees, who complete evaluative and situational reports which are transmitted to a computer via a radio operator. Messages introduced into the system are processed by various personnel and the CCC and then delivered to controllers for evaluation. The field exercise data acquisition is simulated through random message generation based on pertinent values such as



TAR = TASK ANALYSIS, REFEREE; TAO = TASK ANALYSIS, RADIO OPERATOR; TAC = TASK ANALYSIS, COMPUTER
TAN = TASK ANALYSIS, CONTROLLER

Figure 1. Schematic of message processing flow.

message length, type, and arrival time. Each generated message is then processed through the referee → radio operator → CCC → controller network, and processing time is determined along with a number of other descriptive indices.

Each simulated referee in the left to right message processing flow of Figure 1 performs some appropriate procedure on the simulated message(s) received. This is shown symbolically by a circle in which TAR (Task Analysis, Referee) appears. A message then passes to the corresponding radio operator (one of RO_1 through RO_{27}) for processing in accordance with some specified task analysis procedure, circle TAO (Task Analysis, Operator).

Up to 27 simulated messages, each processed by a different radio operator, could then be ready for entry into the CCC. Entry into the simulated CCC for any given message is made over the communication line for the three networks shown. Accordingly, in a given network, there may be up to nine simulated messages competing for the one available CCC input line.

Telecommunication lines are designated in Figure 1, and the resultant queues awaiting CCC actions are designated by ... .

On a "first-in first-out" basis, the CCC processes messages from all of the three networks in accordance with its task analysis procedure--depicted by circle TAC (Task Analysis, Computer). These messages then enter another queue awaiting action by one of three controllers. Each simulated controller then assesses and operates on the oldest message from his network in the queue and performs in accordance with the task analysis for controllers as symbolized by circle TAN.

The loop is closed by the simulated generation of new messages by the controller for input to one of the referees in his nine-way network as a function of a parameter input to the model. Besides the link from the controller to his referees, the referees are also interconnected and may generate new messages as a result of their interactions with one another. Up to 5,400 messages may be included in a given simulation run. During NETMAN's processing of message information, the model places special emphasis on certain human performance features considered to be important in a field operational system of this sort. These include operator stress, fatigue, level of aspiration, proficiency, and precision.

The overall man-machine performance measure calculated by the model, effectiveness, is calculated for each day of the simulated exercise. It is composed of four independent factors--thoroughness, completeness, accuracy, and responsiveness.

Output from the model is presented in the form of computer tabulations and terminal displays. These provide data which promote insight for evaluating alternatives both in terms of absolute and relative value. The printed and displayed output is designed and organized so as to provide results that answer questions of practical importance, such as:

1. What is the average processing time for a message which passes through the network as a function of the frequency of input messages, operator capabilities, and network configuration?

2. How do changes of input parameters affect predicted total man-machine effectiveness values?

3. What is the loading situation relative to idle vs. busy time for referees, radio operators, the CCC, and the controller?

4. How great a stress is placed on the operators? What is the fatigue profile over the mission for each type of personnel?

5. Would changes in the task organization of one or more operators materially affect average processing time and system effectiveness?

6. What are some effects of operator commission and omission errors under various conditions?

7. How would increased personnel training or improved personnel selection affect system performance?

The program presents detailed message processing time and error information, if desired, as well as hourly summary and run summary outputs. The detailed message processing output shows the fine grain of the results of the simulation of each task in the processing of messages.

The hourly summary presents a consolidation of the results of a simulated hour's work across all iterations and includes items such as: number of messages completed, time spent working, end of hour stress level, performance and aspiration, time spent performing various processes, and average time per message.

The simulation run summary, produced after N iterations of the exercise, includes manpower utilization, message processing time, overall effectiveness indicators, and workload summary information.

NETMAN is programmed in FORTRAN IV for the Univac 1108 system. It is organized to allow the user to conduct various numerical "experiments." Each computer run of the model represents a simulation of a field session up to 10 hours in duration conducted under conditions as specified by input parameters. Examples of exercise input parameters include the frequency of messages entered to the system, the number of operators, and the speed and aspiration levels of these operators.

A full model description is contained in Siegel, Leahy, and Wolf (1977) together with a discussion on model utilization, program flow charts, subroutine definitions, user input-output formats, and task analyses. Recent revisions to the model are described in the updated user's manual (Leahy, Siegel, and Wolf, 1980) and a full historical summary has been prepared (Siegel and Wolf, in press).

The EMARS Concept

The EMARS, one of the major concerns of this report, is conceived (Siegel et al., 1980) as a computer assisted, exercise command and control system with capability to support field exercises conducted by the Army up to and including those at the Company level. While deployed operationally, each EMARS system is outfitted for sustained operation at Division level headquarters in which it supports successive Army combat unit exercises. EMARS fully exploits the potential of computer assisted tactical exercise monitoring as a training and testing medium.

The overall EMARS functions include:

1. accepting and processing digital data and information
2. generating situation displays
3. assessing performance and generating objective scores for individual and combined military units at all tested levels by time period
4. supporting exercises up to four days in duration

5. providing multiple hard copy results--maps, records, scores, and comments.

Overall System Description

The EMARS concept includes a system which is contained in a single van and is fully transportable. Figure 2 presents an external conception of the system and Figure 3 presents a preliminary conception of the internal arrangement of the persons and equipments in the system.

The personnel complement, other than system maintenance personnel, consists of five persons: personnel/logistics monitor (PER/LOG), operations/intelligence monitor (OPS/INT), indirect fire/air space manager (IF/ASM), exercise monitoring officer in charge (EXMOIC), and exercise management information officer in charge (EMIC).

All information processing and exercise monitoring functions are performed by these persons who are tied by communication lines to exercise control personnel at Division. The first three EMARS' personnel, PER/LOG, OPS/INT, and IF/ASM receive situation information, verify it, and enter the information into the computer system for processing and storage. The other personnel, the EXMOIC and the EMIC possess the capability to call information from the system at any point in time and to provide a wide variety of status and performance information for each unit involved in an exercise. All of the personnel possess access to the performance data base and each possesses an interactive terminal with a cathode ray tube.

A hard copy plotter is provided to allow overall presentation of unit disposition, the planned and actual progress of each unit, a time history of the progress of each unit, and significant events affecting progress. Hard copy facsimile can be produced on any cathode ray tube presentation available to the operating personnel. These displays, their formats, frequency of use, criticality, and the anticipated user(s) were described previously (Siegel et al., 1980). In all, the system possesses the capability for automatically producing 23 different types of status or performance reports. These individual reports also form the basis for an "after action review."

Application of NETMAN to EMARS

The NETMAN model possesses several characteristics which allow it to be useful in testing exercise monitoring and control systems. First, NETMAN is based on the logic that the basic unit of measurement

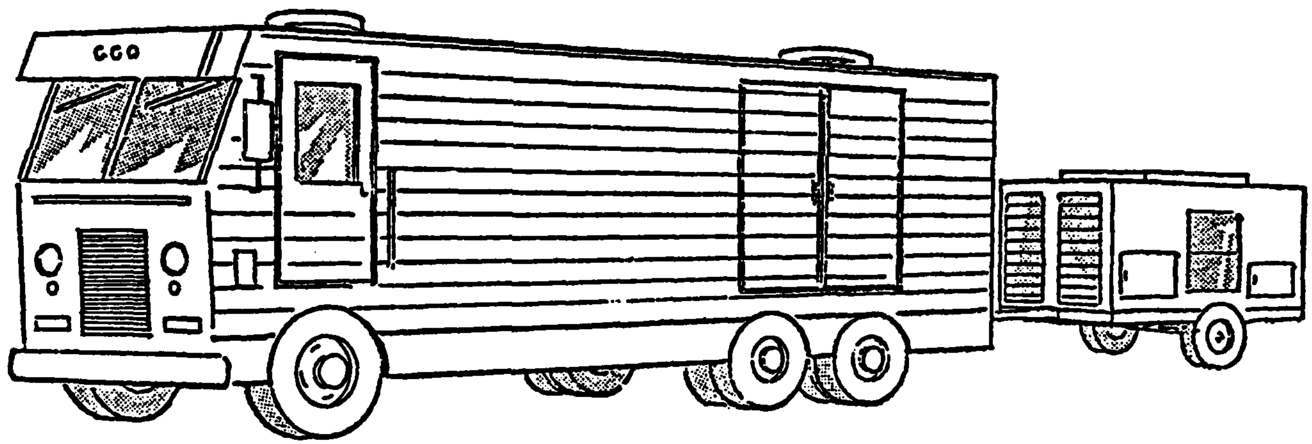


Figure 2. External view of EMARS.

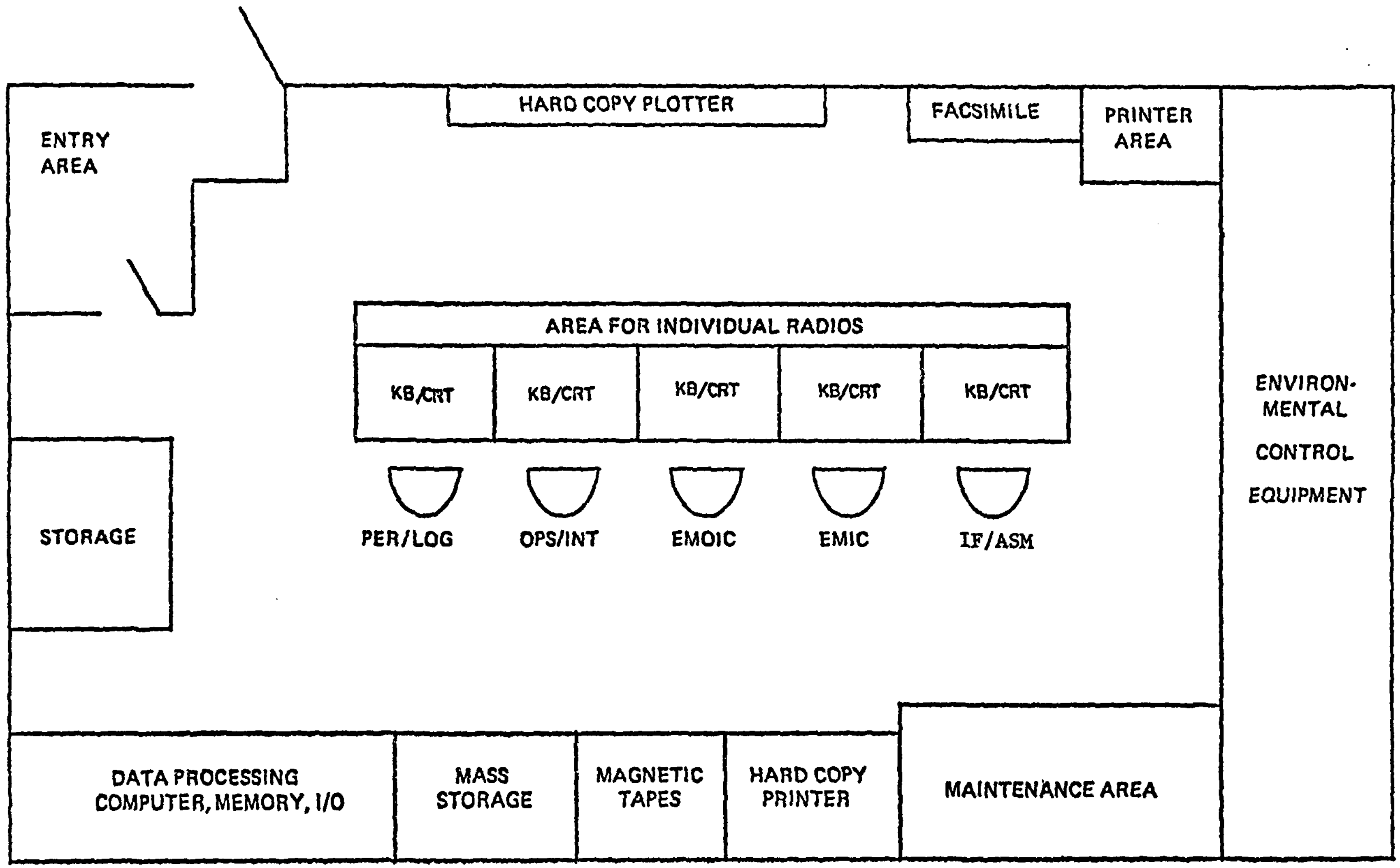


Figure 3. EMARS' internal configuration.

in any communication net is the message, its processing time, and its transmission accuracy. Related to these concerns are NETMAN's ability to allow simulation of the effects of varying message characteristics such as message frequency and length.

Second, the NETMAN model allows the capability to assess and to simulate differentially the effects of a number of important operator variables on system performance. This simulation and assessment may be achieved very systematically. In NETMAN, the performance of each operator is a function of psychological, behavioral, and physiological variables. Operator speed, precision, aspiration, fatigue, and stress tolerance all can be specified and varied to: (1) assess their effects on total system throughput, and (2) enable a simulation to reflect realistically what can be expected in the operation of the system.

Third, different exercise monitoring and control systems impose different behaviorial repertories and task sequences on their operators. These can be differentially represented in the NETMAN model. This flexibility of the NETMAN model has been clearly demonstrated in earlier simulations employing NETMAN. These involved the Army's TOS system (Siegel et al., 1972) and the Marine Corps' Tactical Warfare Simulation Analysis and Evaluation System (TWSEAS) (Siegel et al., 1979).

Content of Subsequent Chapters

Chapter II of this report presents the details of applying the NETMAN model to the EMARS system for the dual purposes on hand. The results are presented in Chapter III and their relationship to the goals of the work is discussed in Chapter IV.

CHAPTER II

METHOD OF APPLICATION OF NETMAN TO EMARS

The effectiveness of the EMARS concept was evaluated by systematically manipulating a number of NETMAN variables. The variables served the role or function assigned to independent variables in a formal experiment. That is, each variable was directly and independently manipulated over several levels. Each selected variable was independently manipulated across four values and the effects of the manipulation on model output were assessed.

Structure of Simulation

The EMARS concept includes a five person crew: personnel/logistics monitor (PER/LOG), operations/intelligence monitor (OPS/INT), indirect fire/air space manager (IF/ASM), exercise management and information controller (EMIC), and exercise monitoring officer in charge (EXMOIC). The first three of these (subsequently called message processing personnel) are conceived to possess the responsibility for receiving and assembling information relative to their respective interest areas, coding the information, and entering the information into the data management system. The final two EMARS personnel (subsequently called monitoring personnel), the EMIC and the EXMOIC, possess decision making responsibility.

Accordingly, the PER/LOG, OPS/INT, and IF/ ASM personnel were conceived as analogous to the radio operators in the NETMAN scheme and the EMIC and the EXMOIC were conceived as controllers in the NETMAN scheme.

Referees are not included in the EMARS concept. Accordingly, the referee representation in NETMAN was not relevant to the present simulation.

Some control systems may be designed so that the functions of one or more positions (levels) are automated or otherwise replaced. To increase the generality of NETMAN and its applicability to such systems, the capability to bypass a system level during message processing was recently added to the NETMAN. Advantage of this feature was taken during the EMARS simulation. The system level bypass feature was implemented to bypass the referee level of the NETMAN model although message generation was simulated. The referee level was bypassed in the

simulation because the EMARS concept assumes field data to be acquired through automatic methods or that field information is delivered manually to the EMARS van. EMARS does not include referees. In EMARS, once the information arrives at the van, it is prepared (message generation) for entry into the computer based system. The result was a more veridical representation of EMARS in NETMAN.

Accordingly, the EMARS simulation involved three NETMAN levels. The assumed analogies between NETMAN and EMARS are:

	NETMAN	EMARS
Position(s)	RO Controller	PER/LOG, OPS/INT, IF/ASM, EXMOIC, EMIC
Processor	Computer	Computer

This organization allowed full simulation of the EMARS including receipt of field based information by EMARS' message processing personnel, (PER/LOG, OPS/INT, and IF/ASM), entry of these data by EMARS' personnel into a computer based management system and processing of these data by the computer, and action on the basis of the data by EMARS' monitoring personnel (EMIC and EXMOIC).

Stated alternatively, the EMARS' personnel, their functions, and their numbers, were defined in NETMAN as two operating networks. In each network, three levels were represented: (1) PER/LOG, OPS/INT, and IF/ASM, (2) computer and its systems, and (3) EMIC and EXMOIC.

Figure 4 presents the representation of each of the EMARS system within the general NETMAN flow.

Task Analyses

The NETMAN model requires as input a task analysis which reflects the task elements required for the performance of each task of each of the simulated personnel.

Task analytic input data for each of the simulated EMARS' positions are presented in Tables 1 and 2. Figures 5 and 6 present the flow of the task analysis for each position.

In Tables 1 and 2, each task element is operationalized by its mean time in seconds for completion, the standard deviation of this time, and the probability that the element will be successfully performed.

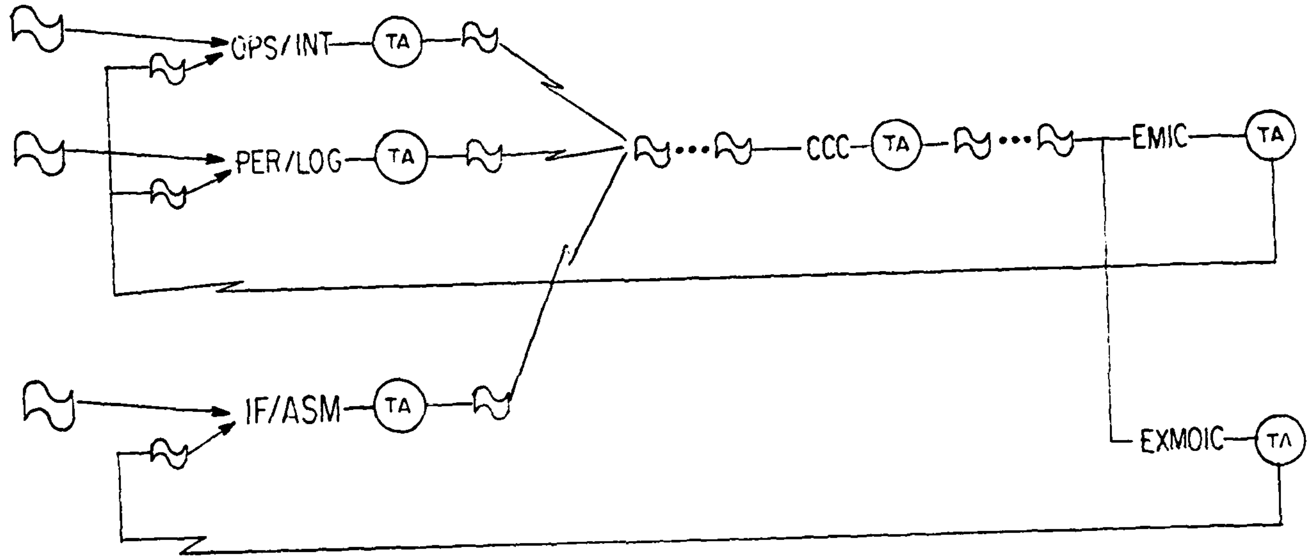


Figure 4. Schematic of EMARS' simulation of message flow.

Table 1

Task Analysis for PER/LOG, OPS/INT, and IF/ASM EMARS' Personnel

Task Elements	Time (seconds) Mean	S.D.	Success Probability	Next Element If Present Element Succeeds	Fails
1. Receive and transcribe	80.00	30.00	.98	2	1
2. Check, edit, and query	30.00	12.00	.98	3	2
3. Code	15.00	3.00	.98	4	3
4. Type	85.00	37.00	.98	5	4
5. Verify	20.00	12.00	.98	6	3
6. End	0.	0.	1.0		

Table 2

Task Analysis for
EMIC and EXMOIC EMARS' Personnel

Task Elements	Time (seconds) Mean	S. D.	Success Probability	Next Element If Present Element Succeeds	Fails
1. Observe CRT message	0.10	0.10	.99	2	1
2. Decide	5.00	2.00	.75	3	9
3. Query (Type)	3.00	2.00	.99	4	3
4. Observe/decide	20.00	10.00	.75	5	6
5. Get hard copy	6.00	0.50	.99	6	5
6. Query (Type)	3.00	2.00	.99	7	6
7. Observe	20.00	10.00	.75	8	9
8. Talk	160.00	60.00	.99	9	8
9. End	0.01	0.01	1.0		

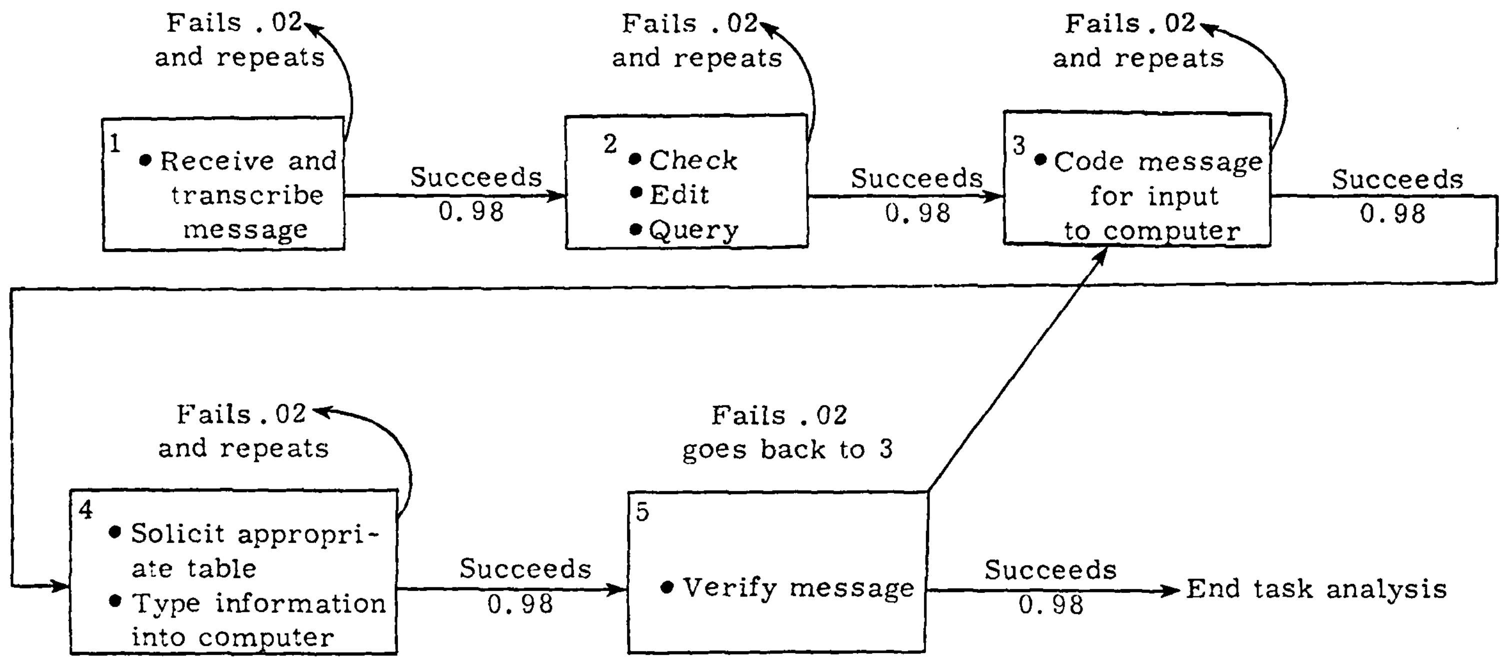


Figure 5. Work flow for PER/LOG, OPS/INT, and IF/ASM EMARS' personnel.

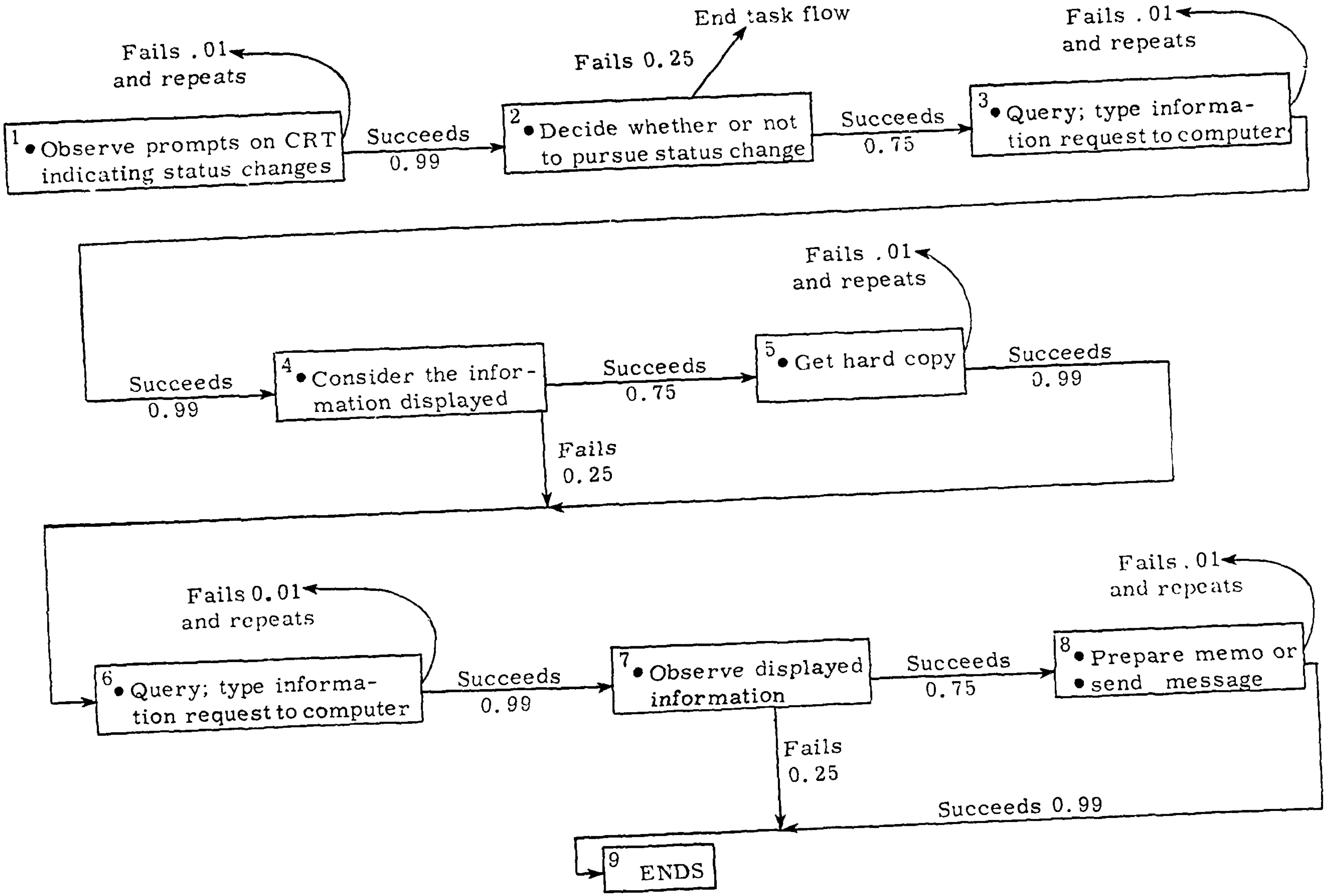


Figure 6. Work flow for EMIC and EXMOIC EMARS' personnel.

The task element times were largely derived from measurements of the time to complete such task elements on current systems. The data are believed to represent best available estimates.

The first two task element times for the PER/LOG, OPS/INT, and the IF/ASM's task analysis (Table 1) were derived by partitioning the measured time for TWSEAS' radio operators to transmit a message (except in EMARS, the personnel received the message). The last three task element times were derived through a set of measurements of the time required by a program staff member to code, type, and verify a number of TWSEAS messages.

The task element time assignments for the EMIC and the EXMOIC (Table 2) were derived from stop watch measurements of the time required by a program staff member to perform each of the task elements at an in-house cathode ray tube terminal. Task elements 1 and 2 for the EMIC and the EXMOIC were the time required, on the average, to read a CRT alerting message and thoughtfully decide on a course of action. The third and the sixth task element times represented the mean time and its standard deviation to type a two or three word command into a computer. The time for the fourth and seventh task elements of the EMIC and EXMOIC were based on estimates of the time to study a chart or a graph and to derive relevant information. The time for task element 5 of the personnel at this system level was the measured time for a conventional photocopier to produce a copy. Finally, the time for task element 8 was the mean total time (and its standard deviation) required by TWSEAS' referees to compose a message.

Task Flow

The simulated task element flow for the PER/LOG, OPS/INT and IF/ASM personnel of the EMARS concept is presented in Figure 5. The first task element represents the time to receive and transcribe a message. The second element embodies the operators' performance in checking and editing the transcribed message and making queries about its contents, intent, or classification. The next element represents the behaviors necessary to code the message for input into the computer. Task element 4 indicates the time necessary to enter the appropriately coded message into the computer. This requires specifying the nature of the data and typing it into the computer. The final element expresses the time needed to verify thoughtfully the information entered and for storing the information in the data base. The act of storing the data was assumed to generate an alerting message on the CRT of the EMIC or EXMOIC.

The probability of successfully performing the first four task elements was set at 0.98. For these four task elements, two percent of the time, an error was assumed to occur, to be detected, and to be corrected by the operator who repeats the necessary element. The possibility was

assumed that a conceptual error in coding would be made by the operator and that the error would escape detection until the final verification element. Therefore, an error detected during the performance of the fifth element required return to the third element--the coding element. This means that the third, fourth, and fifth elements needed to be repeated by the simulated operator.

The structuring and dynamics of the task analysis for the monitors, the EMIC and the EXMOIC, are presented in Figure 6. The first element is indicative of the time to read a one or a two word alerting message presented on a CRT. The message is intended to alert the monitor of a change in the data base. After the reading of the alerting message, the second task element represents the time required to decide whether or not the alert should be followed up; that is, should the new information in the data base be examined. If the simulated operator decides to examine the data base, the task flow proceeds to the next element. However, if the simulated operator decides not to examine the change(s) in the data base, the task flow is stopped. The third task element requires the monitor to solicit the information in the changed data base while the fourth element represents the examination and consideration of this information by the simulated monitor. Also represented in this element is the choice between obtaining a hard copy or not. If the monitor decides on hard copy, the task flow proceeds to task element 5. If not, the flow proceeds to element 6. Task element 6 is another query element in which additional information is accessed. The additional information is studied as element 7. Task element 7 requires a decision on whether to take an action or to end the task flow. The action, embodied in element 8, is either to contact a field observer or to write a memo for future use. When either of the two actions is not performed, task element 8 is skipped and the task flow is terminated at element 9.

Parametrically Treated Variables

Seven NETMAN input variables were selected for parametric manipulation in the present work--four physical and three operator parameters. These parameters, along with their variation over model runs in the EMARS simulation, are presented in Table 3.

The first two physical factors were concerned with the number of messages involved. The number of messages, of course, determines the load on the system and the stress on the simulated personnel. The next two physical factors were concerned with the length of the messages: (1) received by the processing personnel, and (2) received by the monitors.

Table 3

Parametric Variation for Each EMARS Run

	Baseline	Run 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Control
Number of messages generated per stimulus message	1	2	3	4																				1
Message frequency per hour																								
Mean	3				10	20	30																	1
S.D.	2				4	8	16																	1
Field message length (No. of characters)																								
Mean	30							10	100	1000														22
S.D.	10							3	30	300														0
Message length to staff (No. of characters)																								
Mean	300										50	100	700											200
S.D.	90										15	30	270											33
Operator speed	1.00													0.7	1.3	1.6								.99
Operator precision	1.0																0.8	0.9	1.1					1.0
Level of aspiration	.95																			.80	.90	.99		.95

The operator parameters were concerned with the proficiency of the simulated assigned personnel, their precision, and their level of aspiration.

There were 22 operational computer simulation runs and a baseline run. The operational runs involved a wide spread of variations within each parameter. In each run, only one parameter was varied while all others were held at baseline value. The baseline value of each variable is indicated in a separate column of Table 3. These values were essentially "normal" operating conditions whose output was compared with the output produced by the other parametric variations listed.

The "control" column of Table 3 represents the input to a previously completed simulation run for the TWSEAS system (Siegel, Leahy, and Wolf, 1979). The run selected is the available prior run which most closely approaches the baseline parameters of the present simulations. The representation of the TWSEAS system in NETMAN is shown in Figure 7.

Each of the runs was essentially a replication of the baseline run with one parameter varied. All the input values listed under the "Baseline" heading of Table 3 were included with the exception that the numerical value specified under the appropriate run number was substituted for the corresponding baseline value. For example, in run 1 the number of messages generated per stimulus message was set to two--the two was substituted for the baseline value of one message generated per stimulus message. Likewise in run 4, the ten was substituted for the mean of three messages per hour in the baseline and four was substituted for the standard deviation of two messages per hour.

Each run simulated system performance over a four hour period and was based on five iterations. This number of iterations has been found previously to yield a stable result.

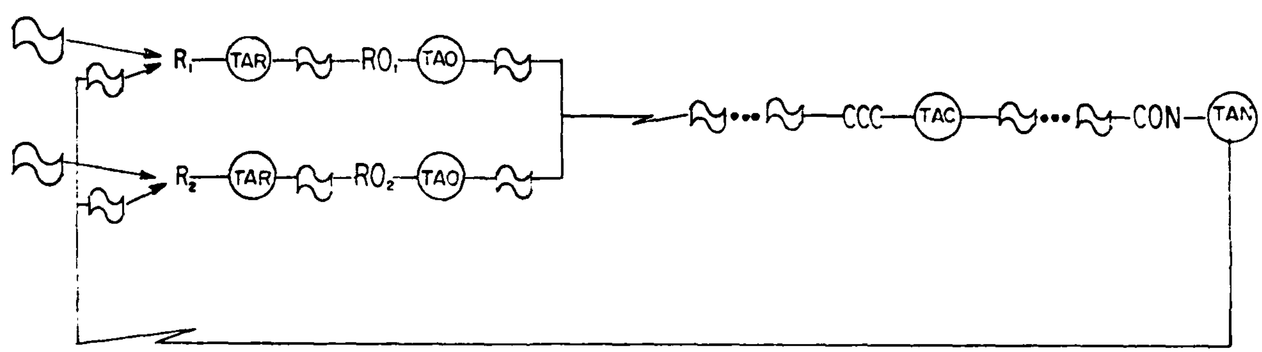


Figure 7. Schematic of TWSEAS simulation of message flow.

CHAPTER III

RESULTS AND DISCUSSION

The parametric variations described earlier led to a variety of data which were employed to evaluate both the EMARS system and the utility of the NETMAN model for such system evaluative purposes.

Message Completion

The number of messages moving through the simulated networks was manipulated by varying two NETMAN input variables: (1) the number of messages generated per stimulus messages, and (2) the number of stimulus messages per processing person per hour (see Table 3). Functionally, both variables had the same effect--either to augment or attenuate message frequency.

The number of simulated messages generated per stimulus message was either 1 (baseline), 2, 3, or 4 (runs 1, 2, and 3 of Table 3) and the mean message frequency was either 3 (baseline), 10, 20, or 30 per hour (runs 4, 5, and 6 of Table 3). This translates to a message frequency, on the average, of 3 (baseline), 6, 9, 10, 12, 20, or 30 per operator per hour. The results of these simulations differentiated on the basis of operator type (PER/LOG, OPS/INT, and IF/ASM combined or EXMOIC and EMIC combined) are presented in Figure 8 in which the number of messages completed is plotted as a function of the mean message frequency.

The effects of increasing the mean message frequency were to increase substantially the number of messages completed. The rate of change was not constant across the rather large increase in message frequency. Rather, the distribution of the messages completed for both the processing personnel (PER/LOG, OPS/INT, and IF/ASM) and the monitors (EXMOIC and EMIC) tended to be ogival. A positive rate of change was observed in the number of messages completed up to a mean message frequency of about 10 per hour per operator. Message frequencies above 10 tended to be associated with increasingly smaller changes in the rate of messages completed. This suggests an upper level for the EMARS system of about 10 messages per operator per hour.

Comparing the messages completed across personnel levels indicated an increasingly large difference as message frequency increased. These differences were probably due to the fact that the two simulated communication nets had different simulated work loads. The first net,

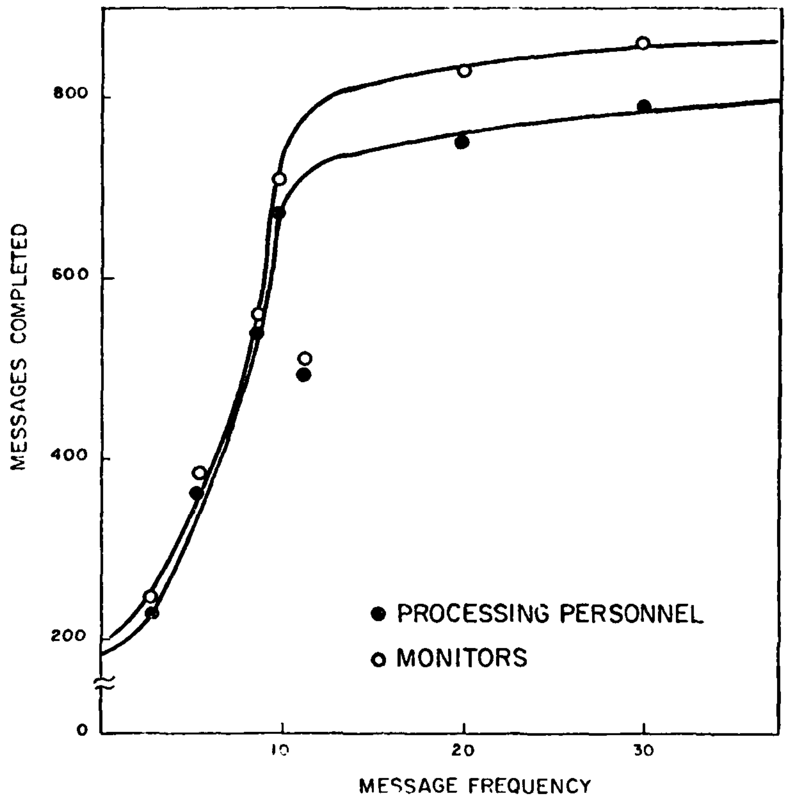


Figure 8. Number of messages completed as a function of message frequency per hour per operator.

consisted of three persons (PER/LOG, OPS/INT, and EXMOIC) while the second net was composed of two persons (IF/ASM and EMIC). Accordingly, the simulated monitor in the second net had to process more output to keep up with the processing personnel at the first level. This finding suggests that EMARS' function might be improved by adding a monitor.

However, regardless of the differences between levels, the most relevant finding concerned the increasingly large number of messages completed. The positive relationship observed between messages completed and message frequency was apparently achieved because of the ability of the simulated EMARS' personnel to adjust to the changes in demand. The message processing was accelerated by two related operator adjustments: (1) the time per message was reduced--the operators worked faster, and (2) the time spent working increased. These adjustments are reflected in Figure 9 in which time per message and percentage time busy are plotted as a function of message frequency.

The time per message declined [Figure 9 (A)] with increases in the message frequency. This decline was most apparent for the processing personnel. For these persons, the processing time per message decreased by approximately twenty percent as message frequency increased from 3 to 30 per operator per hour.

Less decline was found in the monitors' processing time per message. Here, the decline was only about six percent of the maximum. This lesser time decline may be due to the unequal work load between the two levels. The monitors, possessing a heavier work load, may have been forced to speed up earlier to their maximum rate and to level off at this maximum.

The results for the other NETMAN output (percentage time busy), which reflected the simulated behavior of the EMARS' personnel, are presented in Figure 9(B). The distributions of the busy time were similar to the distributions of the messages completed. That is, they were somewhat positively accelerated up to a frequency of 10 messages per hour and negatively accelerated thereafter. Apparently, the increased message load was met by the simulated operators working more and working faster.

Stress

Concomitant with the two adjustments in simulated performance were concurrent and interdependent changes in the mean stress of the simulated personnel. Succinctly, NETMAN operates such that, as percentage time busy increases, stress on the simulated operators increases; as stress increases the pace of the simulated operators increases and the time for message completion decreases. The mean stress, differentiated on the basis of type of operator, is plotted as a function of message frequency in Figure 10. The distributions of stress tended to be flat until a moderate message frequency value was reached. At this point, mean stress accelerated over the remaining message frequencies. The value at which the stress level changed varied across operator levels. The processing personnel's stress was invariant up to a message frequency of nine. Beyond that value, stress increased at a decreasing rate and reached 1.90 at the highest message frequency of 30. The monitors' mean stress was constant up to 10 messages per hour per operator. Then, the stress level increased and reached a value of 1.70 at a message frequency of 30. In neither case did the mean stress appear to asymptote.

Accordingly, it seems that the operators in the EMARS system are placed under moderate stress under higher message frequencies and that methods may be needed to ameliorate their stress.

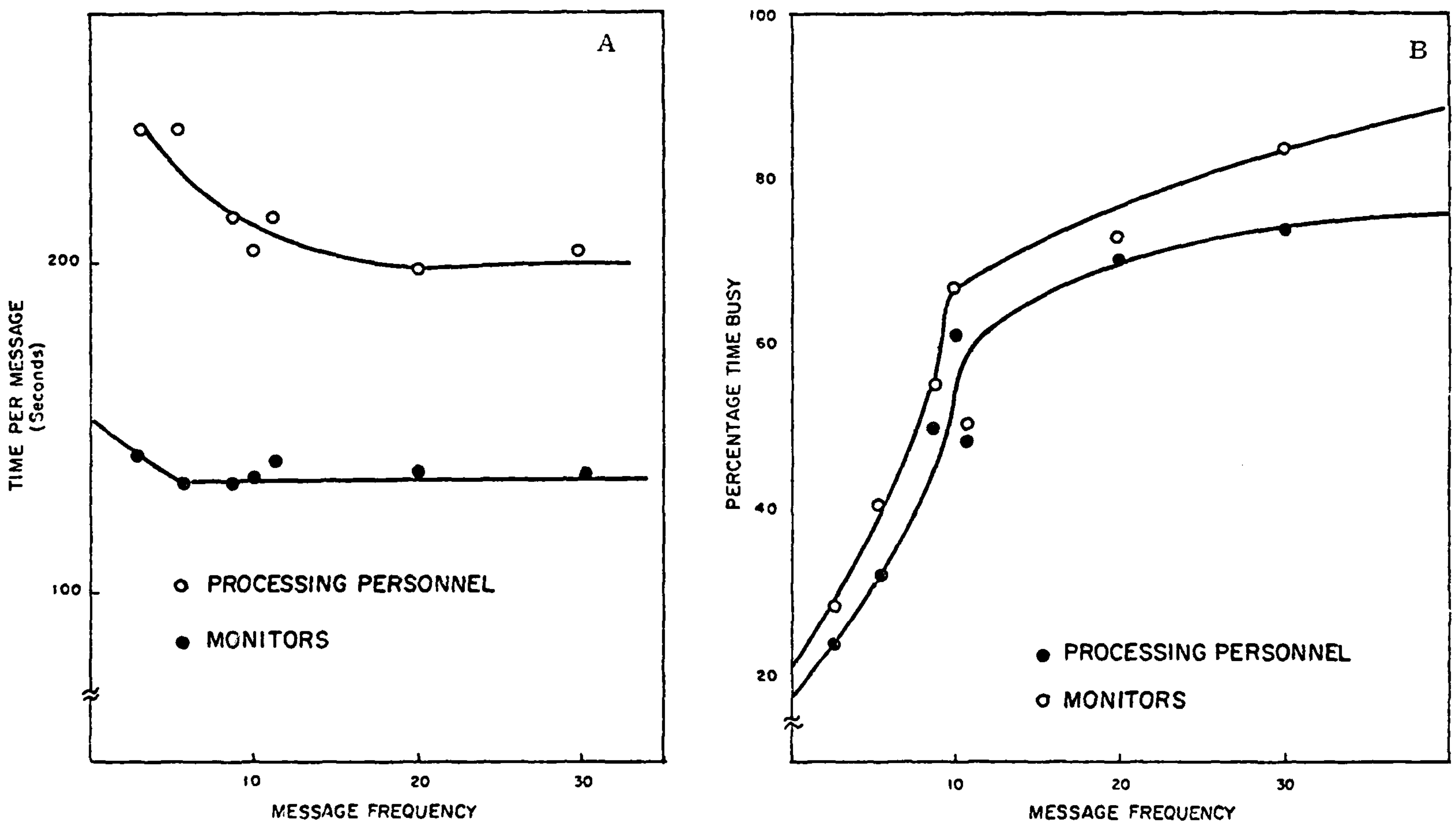


Figure 9. Time per message (A) and percentage time busy (B) as a function of message frequency.

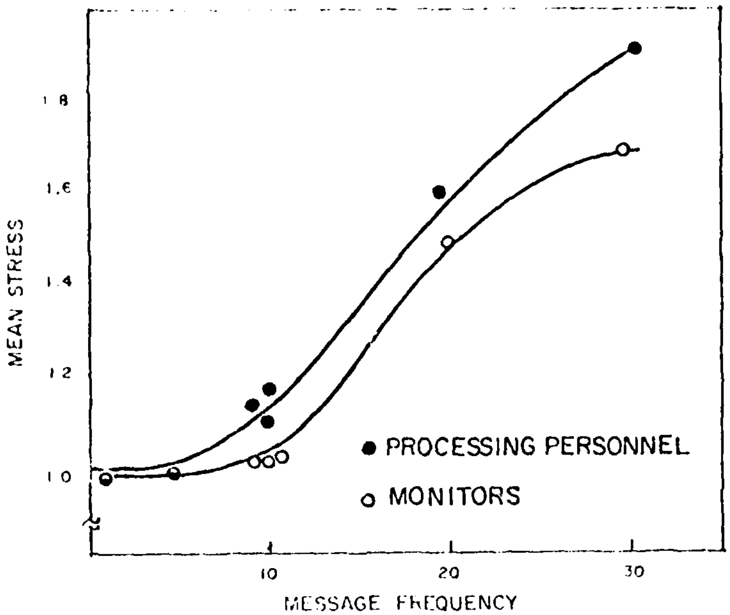


Figure 10. Mean stress as a function of message frequency.

Overall Effectiveness

The NETMAN model also provides a measure of overall effectiveness. The overall effectiveness index, with a range of 0.0 to 1.0, represents a weighted geometric mean of four component measures: (1) thoroughness, (2) completeness, (3) responsiveness, and (4) accuracy. The thoroughness component represents the ratio of messages completed to the total messages available to be started. Completeness is related to the success/failure ratio for task elements across personnel and messages; it can be thought of as the average performance level. Responsiveness is determined as the message processing time, which includes man and computer working time, divided by the total time to process the message, which also includes delays and time spent waiting in queue. Accuracy is a function of information loss within the system.

Overall effectiveness is plotted against message frequency per operator per hour in Figure 11. Over the message frequency range involved, effectiveness varied about eight percent with a range of 0.86 to 0.94. The shallowness of the overall effectiveness decline suggests that EMARS is reasonably suited to a task of handling increasingly greater quantities of incoming messages and moving them through the system. This observation is supported through a comparison of the calculated effectiveness of

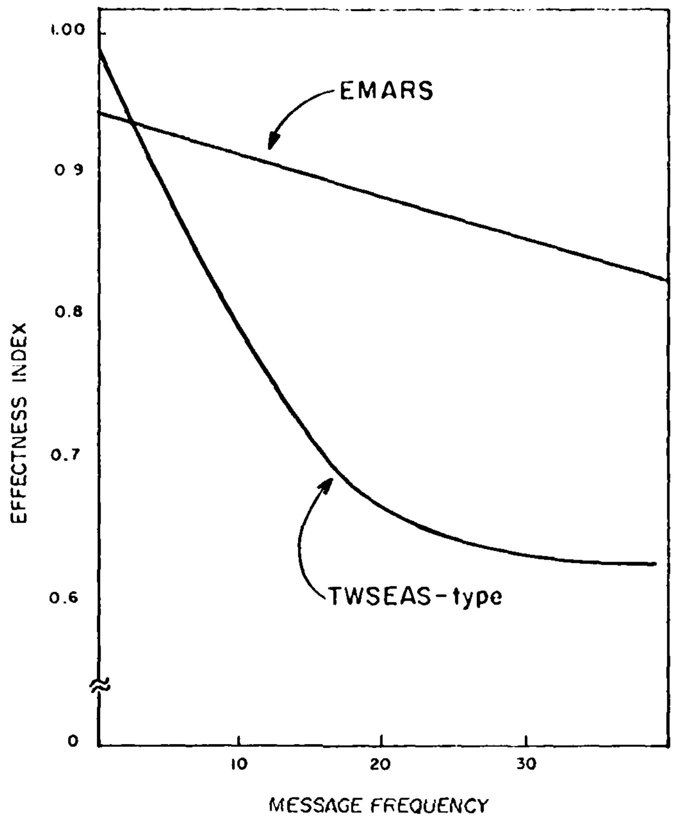


Figure 11. Overall effectiveness for EMARS and TWSEAS-type systems as a function of message frequency.

the EMARS system with the results from the NETMAN sensitivity testing which was based on a TWSEAS-type system (Siegel et al., 1979). As indicated in Figure 11, the overall effectiveness of the TWSEAS-type system was not only considerably lower than EMARS but also the overall effectiveness of the TWSEAS-type system fell to about 0.63 when the message frequency reached 30. The corresponding overall effectiveness for EMARS was 0.86.

Thoroughness

Examination of the components of the overall effectiveness index indicated that the declining relationship was almost exclusively a function of the thoroughness component. The thoroughness index for EMARS declined from 0.93 to 0.67 as message frequency increased from 3 to 30 per hour per operator.

In the NETMAN sensitivity testing with a TWSEAS-type system, changes in message frequency over a range of 5 to 30 (a range comparable to the 3 to 30 range used in the EMARS' evaluation) produced a very strong reduction in thoroughness. With message frequencies of 30, the thoroughness measure for the TWSEAS-type system was between 0.10 and 0.20. This was very much below the 0.67 measure reported for EMARS.

Figure 12 presents the thoroughness index for both systems plotted against message frequency. When message frequency was low, the thoroughness indices for both the EMARS and TWSEAS-type systems were similar. As message frequency increased, the thoroughness for both systems declined. However, there was an increasingly large difference between systems. It appears that the TWSEAS-type system degraded much more rapidly and to much lower level with increases in message frequency than the EMARS system.

Field Message Length

The next set of variable manipulations examined the length of the messages received by the processing personnel. The effects of message lengths of 10, 30, 100, and 1000 characters per message were evaluated.

The relationship between field message length and the number of messages completed is presented in Figure 13. The number of messages completed appeared to be rather independent of field message length up to a length of 1000 characters. The number of messages completed was between 240 and 280 for both the processing personnel and the monitors when the field message length was 10, 30, or 100 characters per message. However, when the length was 1000 characters, the messages completed dropped to about 25 for all of the EMARS personnel. This stability of output was apparently achieved by the concomitant adjustments in the message processing time, as affected by the stress variable within the NETMAN model's logic. However, EMARS seems to be message length sensitive and limiting the number of characters in any message seems indicated for the system.

The time per message is plotted as a function of the field message length in Figure 14. The effects of field message length on time were different for the processing and the monitoring personnel. Changes in field message length had no effect on monitors' times; the times remained constant at around 130 seconds. The monitors' invariant processing times were expected because they receive processed data rather than field messages.

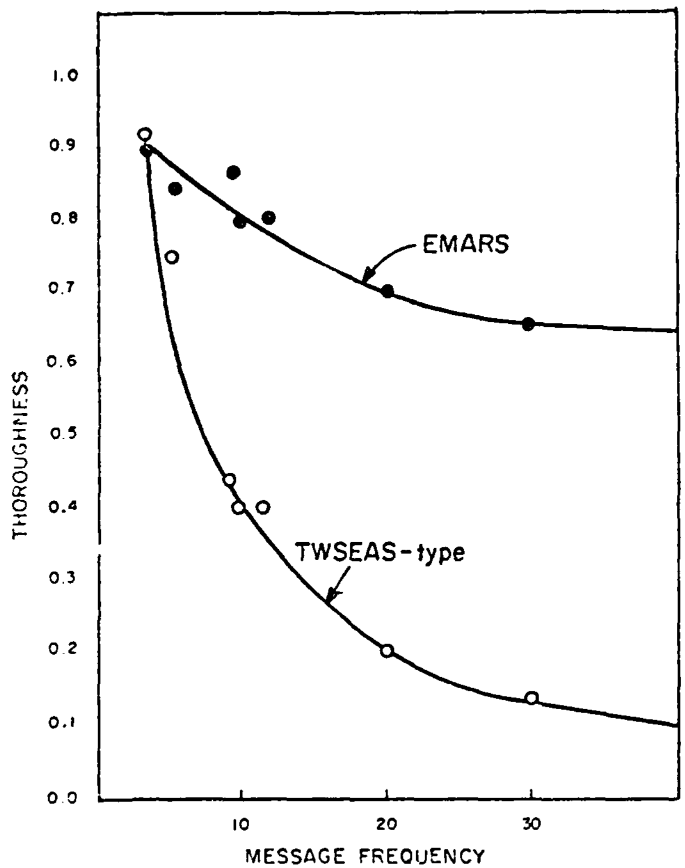


Figure 12. Thoroughness as a function of message frequency.

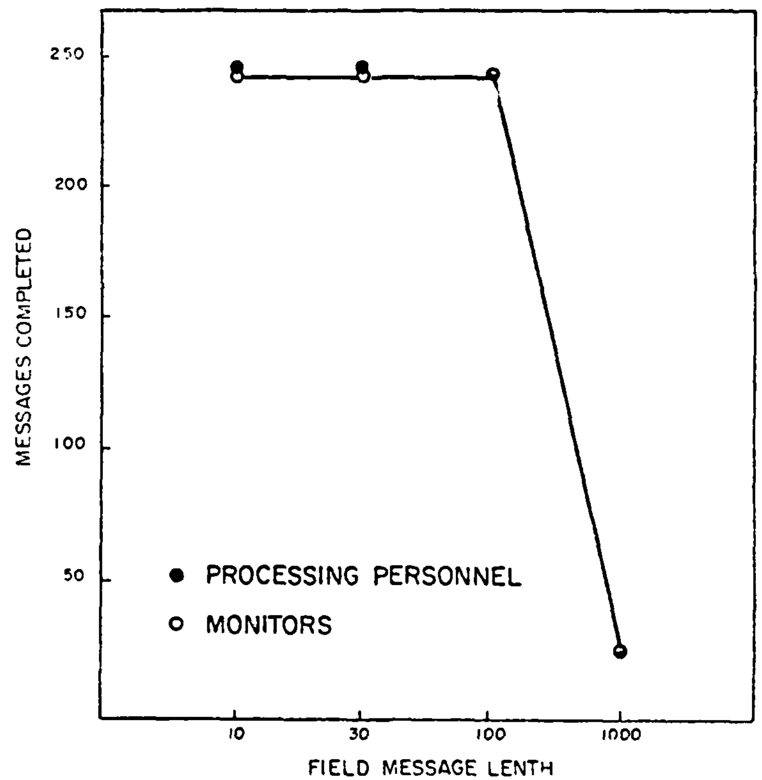


Figure 13. Number of messages completed as a fuction of message length.

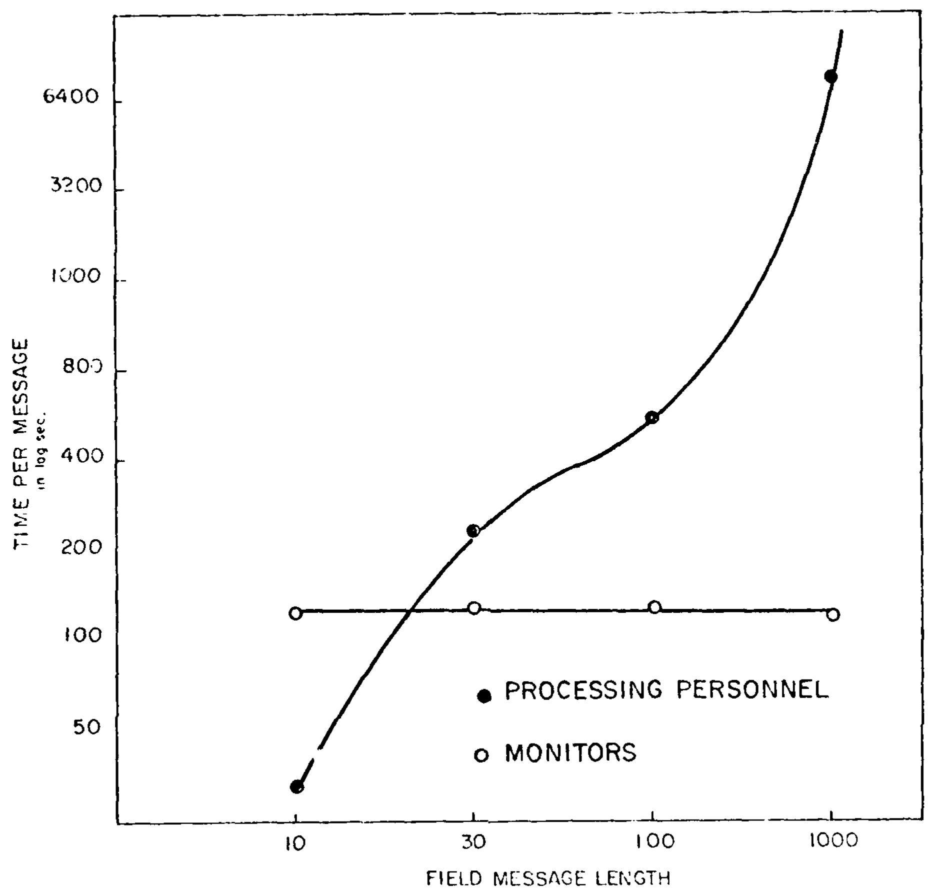


Figure 14. Time per message as a function of field message length.

There was a considerable effect of message length on the message completion time for the processing personnel (Figure 14). It appears that the limits of the EMARS' processing personnel were exceeded when message length was between 100 and 1000 characters.

Further insight into the point at which message processing was affected can be obtained by examining the percentage of time busy for the various operators. This dependent measure is plotted against field message length in Figure 15. The trend of the completion times was again very different across the personnel levels. The percentage time busy for processing personnel increased as the number of characters increased. The percentage time busy for the monitors remained level at lower message lengths but, when message length reached the highest value tested,

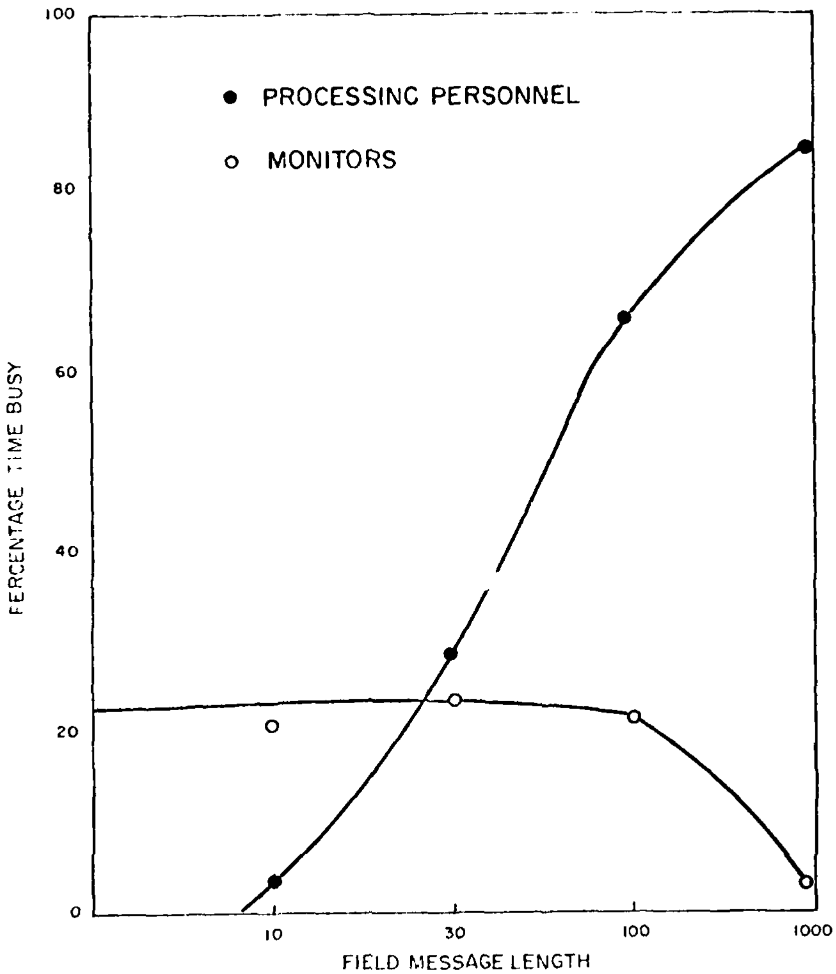


Figure 15. Percentage time busy as a function of message length.

the time busy dropped to a few percent. The inability of the simulated processing personnel to process the extremely long messages (1000 characters) had the effect of virtually stopping all flow into the system's higher levels.

Even the increased stress on the processing personnel, as simulated in the NETMAN model, was not sufficient to offset the effects of 1000 character messages.

The effectiveness measures also reflected the rather strong inhibitory action of increased message length. Overall effectiveness and its components are plotted against field message length in Figure 16. The thoroughness and the responsiveness components both dropped from moderate or high values, when the message length was 100 characters, to low or moderate levels when message length was 1000. The result was a parallel depression of the overall effectiveness index.

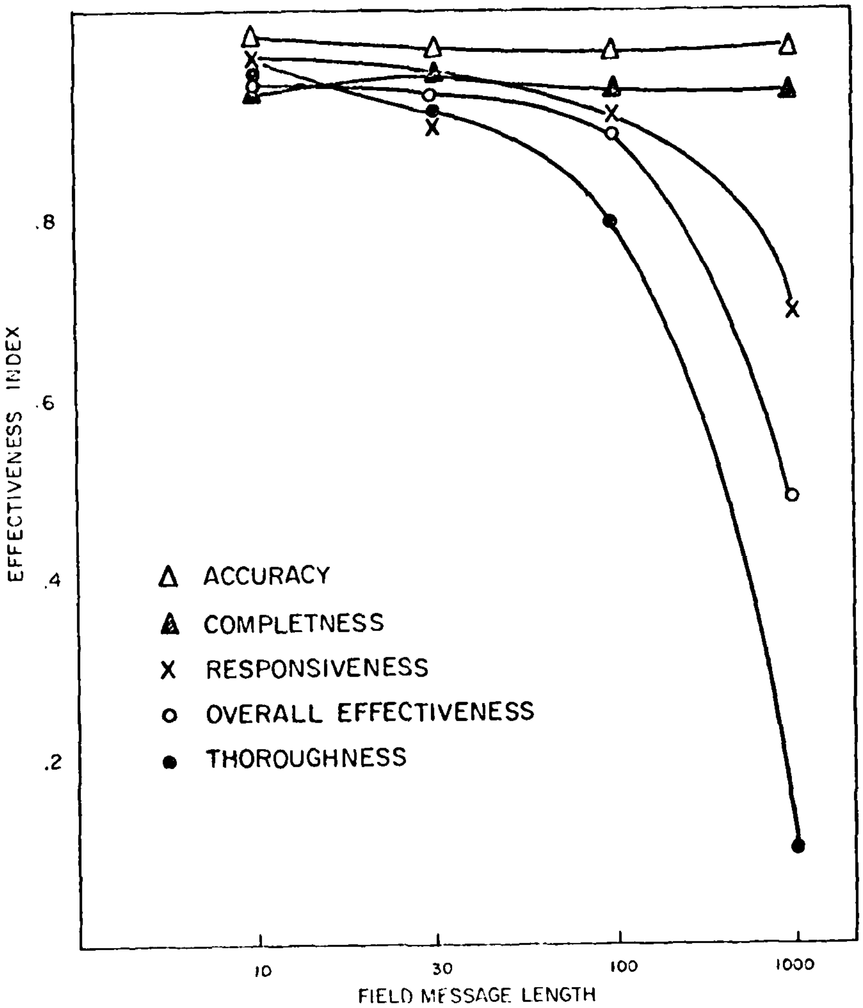


Figure 16. Overall effectiveness and effectiveness components as a function of field message length.

A comparison of the EMARS' effectiveness degradation as a function of message length with the corresponding measure for a TWSEAS-type system suggested greater robustness for the EMARS system. The pertinent data from both the EMARS and TWSEAS-type simulations are presented in Table 4. Some differences in the runs are noted here: (1) in the low to middle range, EMARS' field message length was 30 characters whereas the TWSEAS-type's was 22, and (2) the NETMAN evaluation using the TWSEAS-type structure did not include any field messages longer than 100 characters. Within these limitations, comparisons were possible and are presented in Table 4.

Table 4

Overall Effectiveness and Effectiveness Components Across Changes in Field Message Length for the EMARS (E) and the TWSEAS-Type (T-T) Systems

Field Message Length	Thoroughness		Completeness		Responsiveness		Accuracy		Overall Effectiveness	
	E	T-T	E	T-T	E	T-T	E	T-T	E	T-T
10	.97	.76	.94	.96	.97	.89	.97	1.00	.96	.90
E = 30 T-T = 22	.93	.77	.96	.96	.92	.85	.99	.99	.94	.89
100	.80	.76	.94	.97	.93	.47	.93	.74	.91	.72
1000	.12		.94		.70		.99		.49	

The thoroughness measure for EMARS was observed to be considerably higher across each comparison. In addition, responsiveness was found to be almost twice as high in EMARS as in the TWSEAS-type system when the length was 100. In fact, the responsiveness measure of EMARS was higher at 1000 characters per field message (value of 0.70) than the TWSEAS-type at 100 characters (value of 0.47).

The change in accuracy over the changes in message length was trivial for EMARS. The accuracy values were consistently high (0.97 to 0.99) but, for the 100 characters per message length, the TWSEAS-type system was considerably less accurate (0.74).

The EMARS's showed a five or six point overall effectiveness advantage over the TWSEAS-type system when the message length was low. However, at 100 characters per message, the difference was considerable.

Staff Message Length

The final physical variable examined the effects of message length to the monitors--the EXMOIC and EMIC.

The monitors' time per message completion increased (Figure 17) when message length was greater than 100 characters. This processing time at 700 characters per message, in turn, increased busy time from about 28 percent in the baseline to about 36 percent. The effect of field message length on the overall effectiveness index or on its components was neglible except for the thoroughness component. Essentially, the same effect was reported from the TWSEAS-type sensitivity test (Siegel et al., 1979), i.e., little variability in effectiveness measures as a function of staff message length. The only effect of any consequence was observed in the thoroughness component. Thoroughness values within and between systems were:

Staff Message Length in Characters	Thoroughness: TWSEAS-type	Thoroughness: EMARS
50	.97	.98
100	.98	.98
300	.77	.93
700	(TWSEAS-type sensitivity results were not reported for staff message lengths greater than 300.)	.90

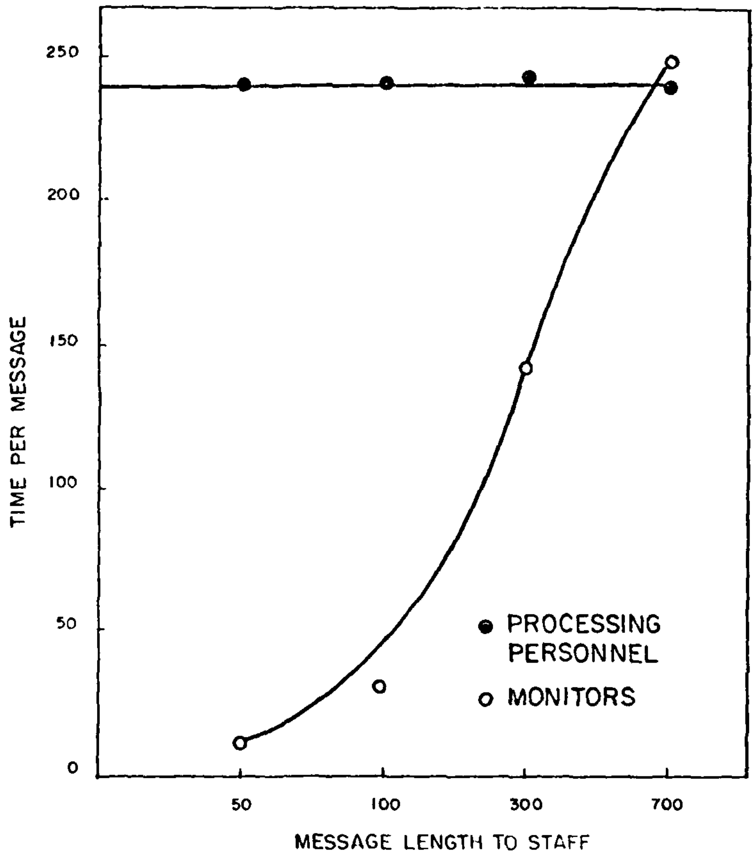


Figure 17. Time per message as a function message length to monitors.

The thoroughness measures for the two systems compared were equivalent and high across the first two staff message lengths--50 and 100 characters in length. However, at a length of 300 characters, the TWSEAS-type's thoroughness dropped sharply to 0.77 whereas that for the EMARS decreased only slightly to 0.93. More importantly, staff message lengths of 700 characters only reduced the thoroughness to 0.90. This value is higher than that observed for the TWSEAS-type when the length was 300 characters.

Behavioral Variables

Three behavioral variables were manipulated in the EMARS' concept evaluation: (1) operator proficiency, (2) operator precision, and (3) operator level of aspiration. The effects of these variables on system performance and on the effectiveness index are examined in this section.

Operator Speed

NETMAN allows simulation of operators of various proficiency (speed) by way of input values. In the EMARS' concept simulation, the effects of operator proficiency were examined over the range of 0.7 (considerably above average) to 1.6 (considerably below average) where 1.0 is average.

The effects of varying simulated operator proficiency on performance are presented in Figure 18 (A) for the number of messages completed and in Figure 18 (B) for the time per message. The proficiency variation had a linear effect on both dependent variables.

As would be anticipated, the number of messages completed was positively related to the proficiency values assigned to the simulated operators. The reduction in messages completed with decreases in simulated operator proficiency was of moderate magnitude. For the processing personnel, the reduction was approximately 14 percent, whereas the reduction for the monitors was about 15 percent, as proficiency varied from 0.7 to 1.6.

As the simulated proficiency increased, the time per message decreased. With decreasing proficiency, there was a tendency for the processing personnel's message completion time to increase at a faster rate than did the message completion time for the monitors. This finding is concordant with the prior implication of any uneven work load across the two levels. The magnitude of the difference between levels was about 42 percent when the operators had 0.7 proficiency assignments. This value increased to about 106 percent when the simulated operators possessed 1.6 proficiency assignments.

The change in time per message was reflected in the percentage time busy. Percentage time busy varied from 23 to 39 percent and 19 to 31 percent when proficiency varied between 0.7 to 1.6 for the processing personnel and the monitors, respectively.

The overall effectiveness index and some of its components also suggested a rather direct effect of operator proficiency on system performance. Thoroughness, responsiveness, and overall effectiveness exhibited sensitive changes in simulated operator proficiency. When proficiency was 0.7, thoroughness rose to 0.94. This thoroughness value was the highest observed throughout this evaluation. As proficiency decreased, thoroughness decreased and was 0.86 when proficiency was 1.6. In a similar manner, responsiveness ranged from 0.95 to 0.79 as proficiency varied from 0.7 to 1.6. Overall effectiveness exhibited similar changes and ranged between 0.94 and 0.89.

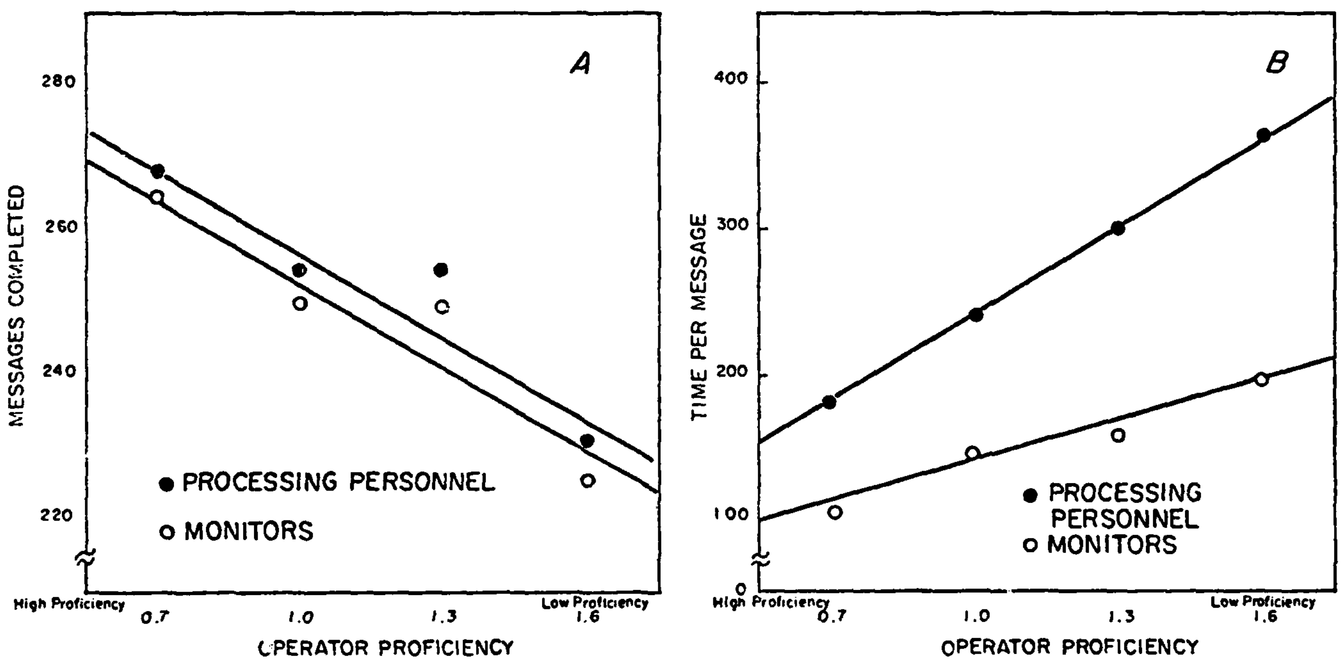


Figure 18. Messages completed (A) and the time per message (B) as a function of operator proficiency.

The effects attributable to manipulations in proficiency were somewhat lower in magnitude as compared with the effects observed for the physical factors. This finding was to be expected and is similar to the results reported in the NETMAN sensitivity tests (Siegel et al., 1979). The proficiency variables had only a limited impact on effectiveness in the TWSEAS-type situation. The values and distributions of the responsiveness and thoroughness measures were very similar between systems.

Precision

Precision, scaled similarly to proficiency, represented the aspect of human error generation. The lower the precision value, the fewer the number of errors that would be expected to enter the data base. The effects of precision on the EMARS were evaluated by examining four precision values--0.8, 0.9, 1.0, and 1.1.

The messages completed data and the corresponding time per message are plotted against precision in Figure 19. An effect very much like that reported for proficiency was found in the relationship between messages completed and precision [Figure 19(A)]. That is, the number of messages completed tended to be linearly related to simulated precision and similar distributions were evidenced across operator levels. Across operator levels, the degree of the change was also of the same magnitude--about 20 percent.

The similarities between the effects of proficiency and precision were not maintained when the message processing times were considered [Figure 19 (B)]. The time to process a message was somewhat invariant when the simulated precision values were between 0.8 and 1.0 for both the processing personnel and the monitors. Thereafter, time was affected more markedly by proficiency than by precision. Time per message for processing personnel increased from approximately 240 and 394 seconds over the precision values of 0.8 to 1.1. This represents a 64 percent increase. The monitors' average processing time increase was somewhat less--46 percent.

The effects of precision on time were reflected in percentage of time busy. The highest percentage time busy was 41 for the processing personnel and 29 for the monitors.

The completeness and responsiveness effectiveness components as well as overall effectiveness varied as a function of simulated precision. One of these measures, responsiveness, was also found to vary

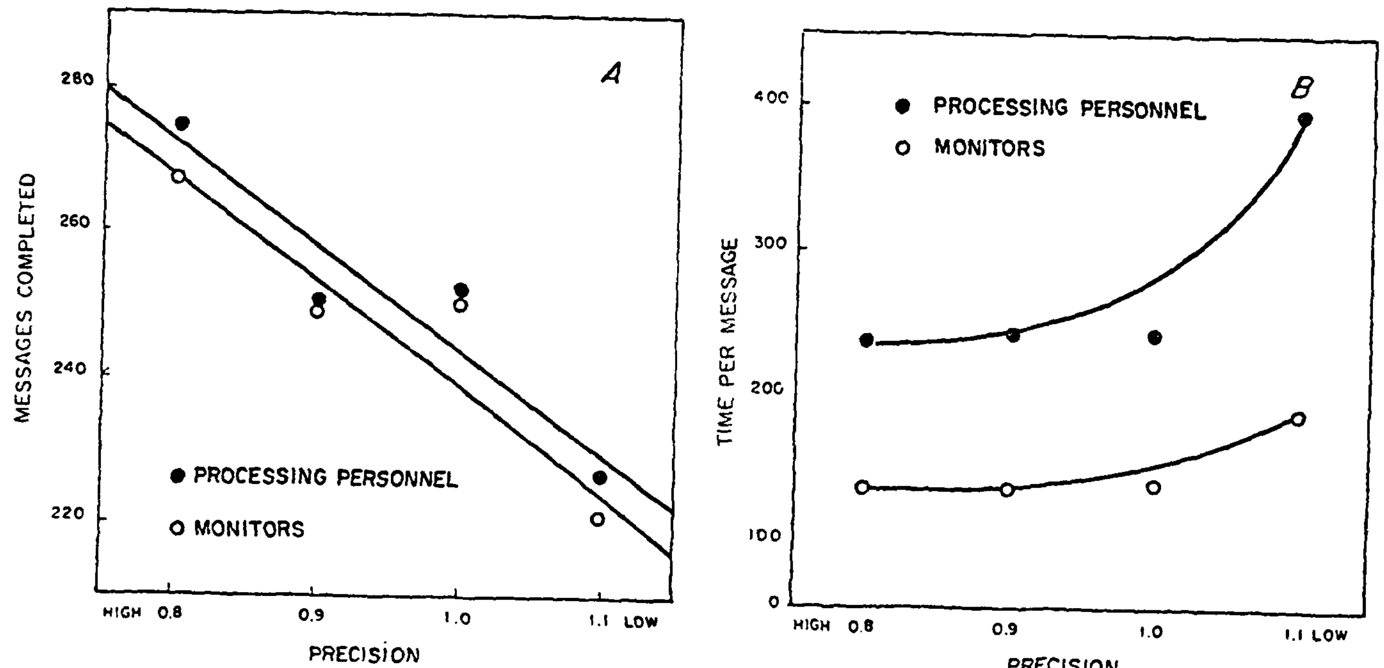


Figure 19. Messages completed (A) and time per message (B) as a function of simulated operator precision.

as a function of precision in the TWSEAS-type sensitivity test (Siegel et al., 1979). A comparison of the effects of simulated operator precision on the responsiveness component for the EMARS and the TWSEAS-type systems is presented below:

Precision	Responsiveness	
	EMARS	TWSEAS-type
0.8 (high)	0.92	---
0.9	0.92	0.92
1.0	0.92	0.89
1.1 (low)	0.78	0.50

While the precision value for more precise operators was generally high for both systems, the magnitude of the drop was greater for the TWSEAS-type system than for the EMARS when less precise simulated operators were involved. The responsiveness for the former was 0.50 and that for the latter 0.78 when precision was 1.1 (low).

The completeness component also varied as simulated operator precision was varied. Completeness of the EMARS system, measured as the ratio of successfully completed task elements to the total number of elements, acted very much like responsiveness. The completeness index was high and stable over the moderate and high simulated operator precision levels but decreased when simulated precision was 1.1 (low). The drop was from an average of 0.95 to a level of 0.82.

Aspiration

The effect of operator's level of aspiration depends, in the NETMAN model, on a complex interaction with the current levels of performance and stress on the simulated operators. Simulated performance is affected under four conditions in NETMAN:

1. when the simulated personnel are performing below their level of aspiration and are only mildly stressed, there is a positive pace adjustment factor due to aspiration.
2. when the simulated personnel are performing above their level of aspiration and stress is low, there is a decrease in the operator's level of aspiration.

3. when the simulated personnel are performing below their level of aspiration but are under high stress, the level of aspiration is reduced and the speed of performance is degraded.

4. when the personnel are performing at their level of aspiration but are under high stress there is an increase in stress.

Aspiration level, with a range of 0.8 to 1.0, is scaled directly in NETMAN. That is, higher values reflect higher aspiration levels. To evaluate the effects of operator aspiration on EMARS' performance, in separate runs, operator aspiration was set at: 0.8, 0.9, 0.95, and 0.99.

Varying the simulated aspiration level of the simulated operators had a moderate effect on both system performance and effectiveness. There was an increase in the number of messages completed (about 10 percent) and in completeness (about 5 percent).

Examination of the final aspiration levels indicated them to be such as to be active within the model. The assigned and final aspiration levels were:

Aspiration Levels

	Final	
Assigned	Processing Personnel	Monitors
0.80	.85	.83
0.90	.92	.91
0.95	.96	.95
0.99	.99	.99

CHAPTER IV

DISCUSSION AND CONCLUSIONS

The evaluation of the EMARS concept employing the NETMAN model progressed along several dimensions. One dimension was concerned with the practical aspects of the EMARS system and its limits and strengths. Another dimension was concerned with a comparison of EMARS' performance and effectiveness with that of TWSEAS-type systems. The final dimension was concerned with evaluating NETMAN'S effectiveness and adaptability as a field exercise monitoring and control system evaluation technique.

EMARS

Evaluating the EMARS system through employment of the NETMAN model required the development of a unique data base and task analysis along with the use of some of the NETMAN model's special features. The evaluation progressed over a parametrically manipulated set of variables grouped into two classes--physical and psychological. The results provided unique insight into the processing capability of EMARS and its strengths and weaknesses. The simulated EMARS system was capable of handling a very high message frequency. The effects of varying field message length were indicative of the limits of the system. Field message lengths over 100 characters or message frequencies over 10 per operator per hour were disruptive to EMARS.

High staff message lengths did not induce the same disruptive effects as field message lengths. The results suggested that the EMARS' effectiveness could also be improved with the addition of one monitor.

Manipulation of psychological factors indicated moderate operator effects. Operator proficiency and precision had linear effects on system performance. System thoroughness, responsiveness, and completeness were found sensitive to simulated proficiency and/or precision. Accordingly, some training requirements seem required for EMARS' personnel.

TWSEAS

When it was possible, the performance and the effectiveness measures obtained from the EMARS' evaluation were compared with prior simulations of a TWSEAS-type system.

Comparing the EMARS with the TWSEAS-type system indicated the EMARS to be more robust and to possess a greater capacity.

Across systems, comparisons rather consistently suggested that the EMARS concept was superior on a variety of measures. The most pronounced differences were observed across message frequency. The overall effectiveness and the thoroughness of the TWSEAS-type system were much more severely degraded than the EMARS as message frequency increased. In fact, the decline for EMARS was somewhat shallow.

Rather large differences between the two system types were also indicated when field message lengths were varied. Even where EMARS' data suggested considerable inability to process very long field message lengths, the EMARS simulation indicated less degradation and EMARS performed comparatively better.

In terms of the psychological variables, for which differences between the systems were not as pronounced, the EMARS system handled messages more effectively across changes in simulated operator precision.

Overall, it appears that the EMARS concept possesses advantages over the TWSEAS-type system in situations in which work load is expected to be moderate to high.

NETMAN Evaluation

One of the purposes of the present work was to test further the capability or utility of the NETMAN model. The test was demonstrative rather than quantitative in nature. The use of NETMAN to evaluate the EMARS demonstrates NETMAN's adaptability by applying NETMAN to a novel communication network and its personnel. The results yielded a variety of insights relative to EMARS' design and the results were rational in terms of direction of change with variation in input parameters. Moreover, NETMAN was sensitive to differences in design characteristics and performance capabilities among the EMARS and TWSEAS-type systems.

NETMAN's sensitivity to differences in the simulated systems suggests that computer modeling of field exercise monitoring and control systems may be a reasonable way to test economically and efficiently the capabilities of such systems while they are in the conceptual stage of development. Moreover, it seems that such evaluations may be completed with some degree of precision and some assurance that the

results will possess meaningful implications for equipment and personnel subsystem design.

The results of the earlier sensitivity and validation tests (Siegel et al., 1979) of NETMAN, along with the current findings, combine to suggest that NETMAN is a useful evaluation tool. Its validity was previously demonstrated and contentions favoring its flexibility and adaptability are supported by the present work.

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GLOSSARY

accuracy	a component of effectiveness, one minus the quotient: total information loss/number of messages completed.
CCC	designation for the central computer which receives messages, processes them, and decodes them for presentation to the controllers.
completeness	the average of all operator performance values taken over all men simulated (i.e., the percentage of task elements performed successfully). A component of the effectiveness.
controller	personnel who receive field information generated by referees, sent by radio operators, and decoded by the computers and who use this information to organize and conduct military field exercises.
effectiveness	measure of the capability of a military unit to perform. A variable determined as a function of the thoroughness, completeness, responsiveness, and accuracy variables.
EMARS	the concept for a system whose purpose is to monitor a military exercise, to assess performance of the military personnel, and to report the results of that assessment.
execution time	the value calculated by a simulation model to represent the actual duration of performance by the simulated operator(s) under current conditions.
exercise monitoring and reporting system	a collection of equipment, personnel procedures, and support capable of assessing proficiency of a military field exercise semiautomatically.
I/O device operator	a person responsible for operation of an input/output device, i.e., computer peripheral device such as a terminal.
iteration	the number of times a simulation situation is repeated in a model to level out stochastic effects.

message	a series of alphanumeric characters, formulated in accordance with a defined procedure which can be transmitted between persons/computers simulated by a model.
message completion	the completion of processing of a message by all operators (and CCC) which processes it in sequence.
NETMAN	a computer simulation model for evaluation of military field exercise management systems in which the processing of each message by each person is simulated.
operator aspiration	the value of operator precision to which a simulated operator aspires; represents a person's goals, expectation, or motivation level.
operator fatigue	a measure of a simulated operator's current level of physical exhaustion as a result of the amount of work, rest, and/or sleep he has experienced.
operator performance	the percentage of tasks completed successfully for a given operator.
operator precision	a measure of a simulated operator's rate of error in performing tasks. (High precision is lower value in NETMAN.)
operator speed	a measure of the relative time in which a person can perform tasks which are predominantly motor oriented, closely related to operator proficiency.
operator stress	a measure of the pressure perceived by one or more operator(s) to complete the remaining simulated subtasks; a measure of simulated operator state of mind involving a threat or negative impact.
radio operator	an operator who processes messages for entry via his radio on a "first-in first-out" basis as they are completed by the referees.
responsiveness	a functional component of effectiveness; a ratio of average message processing time (i.e., referee start to controller end) to average total elapsed message time including idle periods.

stimulus message	a message entered into the system. A stimulus message may generate one or more messages to be processed within the system.
simulated message	a vector whose elements represent the primary characteristics of a military message (e. g. , length in characters, priority, type, and ID number.
simulated model	a representation of behavior and behavioral influence implemented on a digital computer so as to allow prediction of an event or event sets.
stochastic model	a simulation model containing Monte Carlo or game-of-chance techniques involving the use of pseudo-random numbers in the calculations of current model variables.
subtask procedure	a number identifying a subtask which must be successfully completed prior to initiating work on (simulation of) a given subtask.
system entry message or stimulus message	a message which enters the simulated system from outside the system and which, upon entry, generates one or more messages in the simulated system.
task analysis	a sequential list of subtasks which comprise a task; includes data and information describing the performance characteristics of each subtask.
thoroughness	the ratio of the number of messages completed per hour to the total number arriving during the hour. A component of effectiveness.
TWSEAS-like system	a system in which the message generation and processing by operators and computer is handled in a way similar to that utilized in the TWSEAS military system.